AVIAN NEST-SITE SELECTION AND NESTING SUCCESS IN TWO FLORIDA CITRUS GROVES

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ABSTRACT.—We studied nesting success and nest-site selection of Common Ground-Doves (*Columbina passerina*), Northern Mockingbirds (*Mimus polyglottos*), Brown Thrashers (*Toxostoma rufum*), and Northern Cardinals (*Cardinalis cardinalis*) in two Florida citrus groves in spring 1989. Predation resulted in the loss of more than half of all nests. Fish Crows (*Corvus ossifragus*) and rat snakes (*Elaphe obsoleta*) seemed to be the major predators. Nesting success differed between groves and may have resulted from differences in human activities, predator populations, or vegetation structure. Nesting success of Northern Cardinals and Brown Thrashers was lower than that reported in other studies and may have been below the replacement level. Northern Mockingbirds had the most open nest sites with the largest inter-canopy distances (spacing between tree canopies), whereas Brown Thrashers seemed to select areas of the groves with the greatest canopy closure. Northern Cardinals tended to select nest trees with full canopies, perhaps to increase nest concealment. Common Ground-Dove nests were supported by limbs with small angles (degrees deviation from horizontal) and the largest diameters. *Received 21 June, accepted 25 Jan. 1996.*

Citrus groves represent a substantial proportion of breeding habitat available to birds in Florida, yet nest-site selection and nesting success have not been studied in these groves. As Florida habitat is converted to agricultural and other domestic uses, birds are forced to nest in altered habitats for which they may be poorly adapted (e.g., Dow 1969a, Best and Rodenhouse 1984). Our objectives were to document nesting success and characterize nest-site selection in Florida citrus groves. We attempted to answer the following questions: What preferences do breeding birds show in selecting their nest sites? Is nesting success affected by nest-site selection and, if so, how? Are citrus groves suitable nesting habitat for songbirds?

STUDY AREAS AND METHODS

We used two citrus groves on Merritt Island in Brevard County, Florida for study sites. Study grove 1, about 71 ha, was privately owned and managed and was almost entirely planted with orange trees. Study grove 2 was part of the Merritt Island National Wildlife Refuge, was 45 ha, and had a mixture of orange and grapefruit trees. The major herbaceous vegetation in the citrus groves was guinea grass (*Panicum maximum*), poorman's pepper (*Lepidium virginicum*), day-flower (*Commelina diffusa*), Richardia (*Richardia* spp.), prickly sida (*Sida spinosa*), Bermudagrass (*Cynodon dactylon*), vaseygrass (*Paspallum urvellei*), and amaranth (*Amaranthus* spp.). We studied nests from mid-March through early June in 1989. Nests were found by systematically examining each tree in the groves four times

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during the study and by observing bird behavior such as nest building and food carrying. The location of each nest tree was marked on a map of the grove, and a tree adjacent to the nest tree was flagged with colored tape. Nests were monitored on alternate days until they were no longer active. The number and condition of the eggs or young were recorded during each nest visit. Inaccessible nests were checked by using a pole-mounted mirror, by climbing the nest tree, or by using a stepladder in the bed of a pickup truck. As part of a concurrent study, nestlings were weighed and measured during each visit until there was a risk of inducing premature fledging. Broods of Northern Cardinals (*Cardinalis cardinalis*) and Brown Thrashers (*Toxostoma rufum*) also were ligatured during the nestling period to collect food samples (see Johnson et al. 1980). To avoid attracting predators to the nest site, the young were processed at least 10 m from the nest.

Apparent nest success was determined for species with a combined total for both groves of five or more nests with known outcomes. A nest was considered successful if at least one nestling fledged. Nests believed to be deserted due to our monitoring activities were excluded from analyses. Nesting success also was determined by using the number of days of nest exposure (Mayfield 1975). Because the nesting cycles of species breeding in the groves differed in length and, hence, the number of exposure days, nesting success was calculated separately for each species with an adequate sample size. The computer program MICROMORT (Heisey and Fuller 1985) was used to calculate survival rates for the egg and nestling stages and for the entire nesting cycle.

We used chi Square contingency analysis (2 × 3) to test for differences in nesting outcomes between groves. Nests were classified as successful, failed due to predation, or failed due to other causes. Tests were made for all species combined (Common Ground-Doves [*Columbina passerina*], Brown Thrashers, Northern Mockingbirds [*Mimus polyglottos*], and Northern Cardinals) and for each species separately, except for the Northern Mockingbird where the sample size was too small for individual analysis. Red-winged Blackbirds (*Agelaius phoeniceus*) were excluded from both analyses because their nests were found only in Grove 2 in localized areas associated with drainage canals.

After a nest became inactive, we recorded variables characterizing the nest vicinity, nest substrate, and nest position within the substrate. Inter-canopy (between canopy perimeters) and inter-tree (between trunks) distances within and between tree rows were determined. The number of young trees or open spaces where a tree was missing in an area around the nest tree, which included the eight nearest trees, was used as a measure of the openness of the nest tree vicinity. In addition, herbaceous ground cover was sampled within a 1-m^2 quadrat placed 5 m from the trunk of the nest tree in each of the four cardinal directions. Within each quadrat, maximum herbaceous cover height was measured with a tape, and the percent coverages of herbaceous vegetation, bare ground, and plant litter were visually estimated. Citrus type (orange, grapefruit, or hybrid root stock), nest tree height, canopy diameter, and the openness of the nest tree canopy (a visual estimate of the percent closure of the entire canopy) were used to characterize the nest tree. The position of the nest within the substrate was characterized by nest height, relative nest height (the height of the nest divided by the height of the nest tree), the number of limbs supporting the nest, the angles (degrees deviation from horizontal) and diameters of the six largest supporting limbs, and the percent foliage density of the nest tree, estimated visually above and below the nest in the area immediately around the nest. Nest-site measurements also were recorded for nests abandoned before discovery if the species could be identified.

Means and variances were calculated for the variables characterizing the groves and the nest sites of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals. A series of Student's *t*-tests was used to test for differences in variables between the two groves, between the nest sites and the groves in general, and among the

nest sites of the four species. Because sections within the groves were managed differently, tree age and height, canopy diameter, inter-canopy and inter-tree distances, and the amount of herbaceous growth varied. Groves were thus blocked by management units, and vegetation was randomly sampled within each unit. For the analyses, 25 samples were randomly selected from each plot; the distribution of the samples among the management units was proportional to their area. Student's *t*-tests also were used to test for differences in nest-site characteristics between successful and failed nests of Common Ground-Doves, Northern Cardinals, and the combined nests of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals in Grove 1. (Sample sizes for Brown Thrashers and Northern Mockingbirds were too small for separate *t*-tests.) Similarly, successful and failed nests of Common Ground-Doves, Brown Thrashers, Northern Cardinals, and the combined nests of Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals were compared in Grove 2. All significant relationships are presented in the discussion of the selection of nest-site variables. We tested for correlations between variables with Spearman's rank correlation, and found citrus type, inter-tree distance, and the number of limbs supporting the nest to be highly correlated with other variables. Thus, we eliminated them from further consideration. Statistical significance was set at $P \leq 0.05$ for all tests unless otherwise stated.

RESULTS AND DISCUSSION

Fifty-four nests representing five species were found in Grove 1, and 65 nests of seven species were discovered in Grove 2. Of these, the outcome was determined for 46 nests in Grove 1 and 39 nests in Grove 2 (Table 1). The most abundant nests were those of the Northern Cardinal, Brown Thrasher, and Common Ground-Dove, three of the most common species found in the Merritt Island citrus groves (Mitchell et al. 1995).

There are numerous potential predators in and around citrus groves, but Fish Crows (*Corvus ossifragus*) were probably responsible for most of the predation. They were seen near nests that had recently been depredated and were observed carrying nestling birds out of the groves on several occasions. Although otherwise intact, some depredated nests had their linings pulled up, which also lead us to suspect that crows lifted young out of nests. Snakes also were thought to be a significant source of nest loss. A yellow rat snake was seen at the base of a nest tree before our discovery that the nest had been recently depredated, and a yellow rat snake was found in another nest consuming nestlings.

Predation caused the loss of more than two-thirds of all nests in Grove 1 (Table 1). All other causes for nest failure accounted for 11% of the nests. Of the nests found in Grove 1, only 17% were successful. A greater percentage of the known nests was successful in Grove 2 (33%, Table 1). Predation also was responsible for most nest failures in Grove 2, but desertion and other causes accounted for nearly one-fifth of the nesting failures. Red-winged Blackbirds and Brown Thrashers suffered the greatest losses from predation in this grove. Fish Crows were thought to be responsible for four of five instances of predation on Red-winged Black-

TABLE 1

NESTING OUTCOMES (NUMBER OF NESTS) OF THE FIVE MOST COMMON BIRD SPECIES NESTING IN FLORIDA CITRUS GROVES IN SPRING 1989

Species	Total nests		Successful fledging		Predation		Desertion		Other causes of nest failure[a]	
	Gr 1	Gr 2	Gr 1	Gr 2	Gr 1	Gr 2	Gr 1	Gr 2	Gr 1	Gr 2
Common Ground-Dove	11	6	4	4	6	1	1	0	0	1
Brown Thrasher	13	15	0	4	11	9	1	2	1	0
Northern Mockingbird	4	2	0	1	3	0	1	0	0	1
Red-winged Blackbird	0	5	0	0	0	5	0	0	0	0
Northern Cardinal	18	11	4	4	13	4	0	0	1	3
All nests combined	46	39	8	13	33	19	3	2	2	5

[a] Includes deaths from pesticide exposure, starvation, sickness, injury, egg breakage, physical disturbance of the nest by heavy equipment, and unknown causes.

bird nests. The crows were seen either at or near the nest sites before we discovered the nest failures. Two of the thrasher nests were depredated when the citrus fruit was being picked. Because Fish Crows were sighted more often during or immediately after picking activity, we suspect that they caused the thrasher nest losses. We found that thrashers often gave distress calls when we were in the vicinity of their nests. The presence of fruit harvesters likely would have elicited distress calls from thrashers, facilitating the ability of crows to find nests.

The frequency of occurrence of successful and unsuccessful nesting outcomes in the two groves did not differ significantly for Common Ground-Doves ($\chi^2 = 2.4$, df = 2), but it did differ significantly for Brown Thrashers ($\chi^2 = 4.1$), Northern Cardinals ($\chi^2 = 4.4$), and for all species combined ($\chi^2 = 7.6$).

Daily nest survival rates were similar for all species in the egg stage, but varied widely in the nestling stage (Table 2). Brown Thrashers in Grove 1 had the lowest daily nest survival rate for nestlings. Interval survival rates were higher during the egg stage than the nestling stage for Brown Thrashers and Northern Cardinals, but not for Common Ground-Doves. Ground-dove nestlings had a much smaller chance of being destroyed than did the eggs. Nest survival rates spanning both the egg and nestling intervals were greatest for Common Ground-Doves in both groves, followed by Northern Cardinals in Grove 2. Brown Thrashers had the lowest rate of survival, particularly in Grove 1. Survival spanning the entire nesting cycle was higher in Grove 2 than in Grove 1.

Our Mayfield estimates of nesting success for Brown Thrashers and Northern Cardinals in the citrus groves were lower than that reported from

TABLE 2
REPRODUCTIVE SUCCESS OF COMMON GROUND-DOVES, BROWN THRASHERS, AND NORTHERN CARDINALS IN FLORIDA CITRUS GROVES IN SPRING 1989

Species	Grove	Exposure days		Daily nest survival rate		Interval nest survival rate		Nest survival rate across egg and nestling stages
		Egg stage	Nestling stage	Egg stage	Nestling stage	Egg stage	Nestling stage	
Common Ground-Dove	1	118	104	0.915	0.981	0.32	0.81	0.25
	2	57	44	0.947	0.977	0.49	0.78	0.38
Brown Thrasher	1	210	87	0.919	0.736	0.26	0.03	<0.01
	2	281	151	0.947	0.894	0.42	0.29	0.12
Northern Cardinal	1	380	132	0.953	0.864	0.48	0.27	0.13
	2	101	97	0.960	0.887	0.54	0.34	· 0.18

other studies. Mayfield nesting success rates of 44% for Brown Thrashers (Murphy and Fleischer 1986) and 51% for Northern Cardinals (Booth 1980) have been reported. Information on Common Ground-Dove nesting success is scant, but all the young in seven nests located and monitored in a pine plantation survived to fledging (Landers and Buckner 1979).

The high failure rates of Brown Thrasher nests in both groves and of Northern Cardinal nests in Grove 1 attributed to predation may have resulted from our nest monitoring activities. Both species became vocal when field technicians were near the nest sites. Corvids have learned to associate human activity and the response of some nesting passerine species with the presence of active nests (Gottfried and Thompson 1978, Best, pers. obs.) and may have discovered more nests because of our presence. Prior experience with citrus fruit pickers that disturb nesting birds also may have conditioned the crows. Salathe (1987) found that crows that successfully depredated European Coot (*Fulica atra*) nests would extend their searching around the depredated nests, sometimes resulting in destruction of all nests in the area. He concluded that disturbance created by investigator nest monitoring activities affected crow behavior by revealing nests and providing positive reinforcement. When Common Ground-Doves were flushed from the nest, they did not vocalize but sometimes gave a broken wing display. Those doves that did not display were probably inconspicuous to predators. Those that feigned injury sometimes continued the behavior as far as several tree rows away from the nest, perhaps luring predators from the nest site. Although Common-Ground Dove eggs are white, the dense citrus tree canopies probably shielded unattended eggs from view from outside the tree canopy. Because Common Ground-Dove nests were small and often placed on thick

branches, they were more cryptic than the larger nests of Northern Cardinals and Brown Thrashers. These differences may have accounted for the greater nesting success of Common Ground-Doves.

Differences in nesting success between the groves may have resulted from differences in predator populations, human activities, or vegetation structure. Grove 1, where nests suffered higher predation rates, was in a residential area, whereas Grove 2 was within the Merritt Island National Wildlife Refuge where human disturbance may have been less. The vegetation also differed substantially between the two groves and may have influenced nest predation.

Citrus culture operations were largely responsible for differences in grove vegetation. Tree hedging, topping, and skirt pruning influenced the geometry of the tree canopies and the inter-canopy distance, whereas mowing and herbicide application controlled the amount of herbaceous cover. Because the two citrus groves were managed differently, intercanopy distance was greater ($t = -2.0$, $P = 0.05$) in Grove 2 [249.1 ± 223.1 cm ($\bar{x} ±$ SD)] than in Grove 1 (143.4 ± 130.0 cm). Coverage of herbaceous vegetation also was greater ($t = -2.8$, $P = 0.008$) in Grove 2 (44 ± 27%) than in Grove 1 (21 ± 30%), but the opposite was true for bare ground coverage [($t = 3.6$, $P = 0.001$) Grove 2: 10 ± 18% Grove 1: 40 ± 37%.] Less vegetative cover in Grove 1 may have resulted in decreased nest concealment. Although some investigators have found no correlation between nesting cover and nesting success (e.g., Reynolds 1981, Conner et al. 1986), Ehrhart and Conner (1986) reported a correlation between vegetative cover around the nest and nesting success, and Martin and Roper (1988) found predation to be greater around less well-concealed nests.

In addition to altering herbaceous and tree-canopy cover, citrus culture operations may have affected breeding birds by creating disturbances which may have increased nest desertion, particularly during nest building. We suspect this because at least two nests were deserted during construction because of our nest monitoring activities. Also, pesticides, herbicides, and fungicides were routinely applied in the groves and had the potential of poisoning adults and nestlings, resulting in decreased survival and nesting success.

The low nesting success of the breeding birds in the citrus groves suggests that their reproductive output could have been below the replacement level. Such "sink" populations have been documented in other agricultural environments (Rodenhouse and Best 1983, Frawley 1989, Bryan 1990). Low reproductive success per breeding attempt may be compensated for by the long breeding season in Florida. Common Ground-Doves are thought to breed year-round in Florida (Baynard 1909 in

Howell 1932, Landers and Buckner 1979). Northern Mockingbirds and Northern Cardinals nest from March through August (Woolfenden and Rohwer 1969), and Brown Thrashers nest from March through July.

In Grove 1, litter coverage was significantly greater around the nest trees of all species [dove: 55 ± 26% ($\bar{x}$ ± SD), thrasher: 57 ± 26%, mockingbird: 46 ± 24%, cardinal: 60 ± 22%] than in the grove in general (21 ± 25), whereas the coverage of bare ground was significantly less (dove: 23 ± 27%, thrasher: 19 ± 25%, mockingbird: 19 ± 25%, cardinal: 16 ± 19%, grove: 40 ± 37%). Litter and bare ground coverages around nest vicinities in Grove 2 did not differ significantly from the grove overall, but the coverage of herbaceous vegetation around Northern Mockingbird nests (71 ± 19%) was significantly greater than the representative samples of the grove (44 ± 27%). When all species were compared, Northern Mockingbird nest vicinities had significantly more herbaceous vegetation coverage (Table 3). Because Common Ground-Doves, Brown Thrashers, Northern Mockingbirds, and Northern Cardinals commonly forage on the ground (De Graaf et al. 1985), the coverages of herbaceous vegetation, litter, and bare ground may have been important in their selection of a nest vicinity.

Inter-canopy distance was significantly greater around Northern Mockingbird nest trees in Grove 1 (287 ± 135 cm) than in the grove in general (143 ± 130 cm) and was greater around the nest trees of Northern Mockingbirds than around nest trees of the other three species (Table 3). Likewise, the number of young trees or open spaces where a tree was missing near the nest tree, a measure of the openness of the nest vicinity, was greater around Northern Mockingbird nest sites than around nest sites of the other species (Table 3). Woolfenden and Rohwer (1969) described ideal Northern Mockingbird nesting habitat as areas of "spaced" trees and found that nests were usually located in the more sparsely wooded or open sections of their plots. Brown Thrasher nest sites in Grove 2 had significantly smaller inter-canopy distances (144 ± 104 cm) than did a representative sample of the grove (250 ± 223 cm), suggesting that thrashers chose sections of the grove with more closed tree canopies. Inter-canopy distances for Brown Thrasher nest sites were similar in both groves, and differed from those of both mockingbirds and cardinals (Table 3). Fischer (1980) found that Long-billed Thrasher (*Toxostoma longirostre*) nests often were placed in thickets with dense leaf canopies that provided excellent concealment.

Selection of the nest vicinity also may have been influenced by the grove edges because edge habitats may have been important foraging areas. Fichter (1959) concluded that the breeding density of Mourning

TABLE 3

HABITAT VARIABLES ($\bar{x}$ ± SD) CHARACTERIZING NEST SITES[a]

Habitat variables	Common Ground-Dove	Brown Thrasher	Northern Mockingbird	Northern Cardinal
Nest vicinity				
Litter (%)	48 ± 28A	46 ± 30AB	38 ± 25ABC	46 ± 28ABC
Bare ground (%)	20 ± 26A	14 ± 23AB	11 ± 21ABC	16 ± 25ABC
Herbaceous vegetation (%)	22 ± 28A	30 ± 32AB	44 ± 34C	29 ± 30AB
Herbaceous vegetation height (cm)	31 ± 20A	42 ± 27AB	53 ± 21BC	33 ± 20AB
Inter-canopy distance (cm)	179 ± 83A	143 ± 100AB	365 ± 142C	201 ± 121A
Openness near nest tree	1.6 ± 2.3A	1.5 ± 2.0AB	6.0 ± 2.9C	1.7 ± 2.1AB
Nest tree				
Canopy diameter (cm)	518 ± 111A	555 ± 106AB	369 ± 163C	493 ± 138A
Openness of tree canopy (%)	57 ± 28A	61 ± 21AB	55 ± 26ABC	46 ± 26AC
Tree height (cm)	427 ± 81A	476 ± 95B	392 ± 98AC	437 ± 139ABC
Nest placement				
Limb angle (°)	28 ± 30A	35 ± 30AB	69 ± 28C	38 ± 31AB
Limb diameter (cm)	4.4 ± 3.9A	1.8 ± 0.8B	1.5 ± 0.6ABC	1.5 ± 1.6BC
Foliage density above nest[b]	2.5 ± 0.6A	2.3 ± 0.6AB	2.3 ± 0.8ABC	2.3 ± 0.7ABC
Foliage density below nest[b]	1.2 ± 0.5A	1.5 ± 0.6AB	1.9 ± 0.9BC	1.4 ± 0.7ABC
Nest height (cm)	207 ± 43A	297 ± 84B	227 ± 109AC	241 ± 85AC
Relative nest height (%)	49 ± 8A	61 ± 13B	56 ± 18ABC	58 ± 28ABC

[a] For each habitat variable, means not sharing the same letter differed significantly ($P \leq 0.05$) when compared with a series of Student's t-tests.
[b] Foliage density estimates: 1 = cover <25%, 2 = 25–75%, 3 = >75%.

Doves (*Zenaida macroura*) in Idaho apple orchards was not affected as much by nesting cover as it was by the adjacent habitat type.

Canopy diameter, which was negatively correlated (Spearman's rho = −0.595, $P < 0.001$, df = 106) with inter-canopy distance, was smallest for Northern Mockingbird nest trees (Table 3). Also, Northern Mockingbird nest tree canopy diameters in Grove 2 (228 ± 65 cm) were significantly smaller than canopy diameters in the grove overall (528 ± 156 cm).

The openness of the nest-tree canopy was smallest for Northern Cardinals and differed significantly from Brown Thrashers (Table 3). Brown Thrashers chose the tallest trees for nest placement, whereas Northern Mockingbirds tended to place their nests in the shortest trees. When all species were compared, Brown Thrasher nest tree heights differed significantly from those of Common Ground-Doves and Northern Mockingbirds (Table 3).

Angles of limbs supporting mockingbird nests were significantly larger than those of the other species (Table 3). Diameter of limbs supporting nests was similar for all species, except for ground-doves, which had nests supported by larger limbs.

Relative nest height was greatest for Brown Thrashers and smallest for Common Ground-Doves (Table 3). When all species were compared, these two were significantly different from each other.

When successful and unsuccessful nests were compared for each species, only six of the nest site variables seemed to be related to nesting success. The nest vicinity and the placement of the nest in the tree were important, but the nest tree variables did not seem to be. In Grove 1, openness near the nest tree was greater for failed Northern Cardinal nests [1.7 ± 0.9 ($\bar{x}$ ± SD)] than for successful ones (0.5 ± 0.6). Nest concealment is believed to have a large influence on Northern Cardinal success (Ehrhart and Conner 1986), and an open nest vicinity may have facilitated Fish Crows in detecting activity around the nest site. In Grove 2, the height of herbaceous vegetation in the vicinity of Northern Cardinal nests was significantly less for successful nests (33 ± 10 cm) than for unsuccessful nests (55 ± 10 cm), but we have no explanation for this finding. Successful Common Ground-Dove nests in Grove 2 were placed in trees with significantly larger inter-canopy distances (267 ± 28 cm) than were unsuccessful nests (141 ± 51 cm), but we cannot explain this pattern.

Nest placement seemed to affect only Common Ground-Dove nesting success. Successful Common Ground-Dove nests in Grove 2 had supporting limbs with significantly smaller angles (10 ± 17°) than did unsuccessful nests (50 ± 17°). Because Common Ground-Doves build frail

nests with shallow depressions (Howell 1932), they may have chosen smaller-angled limbs for added nest stability. Mourning Doves preferentially place their nests on flat, horizontal limbs (Harris et al. 1963, Knight et al. 1984). Successful Common Ground-Dove nests in Grove 2 also were significantly closer to the ground (180 ± 12 cm) than unsuccessful ones (260 ± 34 cm).

Citrus groves seemed to be suitable breeding habitat for songbirds and doves, based on the number of active nests. Birds seemed to be making choices about the openness of the nest vicinity, the diameter and openness of the tree canopy, tree height, limb angle and diameter, and nest height. These choices may have been based on nest concealment and nest support, but did not necessarily influence nesting outcome. For example, the selection of nest trees with closed canopies did not seem to affect nesting outcome of Brown Thrashers, whereas the choice of small-angled limbs may have increased nesting success for Common Ground-Doves. Because citrus groves are unnatural environments subjected to periodic human disturbances which may inflate predation levels, the choices of some nest site characteristics that are adaptive in natural habitats may be neutral or even maladaptive in citrus groves.

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